ICT-BASED WORK MANAGEMENT TO SUPPORT UNMANNED CONSTRUCTION FOR POST-DISASTER RESTORATION

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ABSTRACT: This paper describes the ICT-based work management to enhance collaborative works and interactive communication, and to grasp significant information in order to support unmanned construction for post-disaster restoration. Firstly, this paper reports the unmanned constructions that have been and are being done in the Unzen restoration project. Secondly, are presented the collaboration, communication, construction and intelligent management (C3IM), which is a comprehensive, web-enabled system to enhance collaborative works and interactive communication, and to grasp significant information in order to support the unmanned construction. Thirdly, are described staple functions of the ICT-based work management Fourth, are reported applications of the ICT-based work management to the unmanned construction of multilayer sediment control dam using sediment forms in the Unzen restoration project. Finally, it shows remarks.

Keywords: *Post-disaster Restoration, Multilayer Sediment Control Dam, Unmanned Construction, ICT-based Work Management, Points on Construction*

1. UNMANNED CONSTRUCTION

In order to remove unstable rocks and sediments deposited by the volcanic eruption of Mt. Unzen-Fugen and to reduce the conditions of risk caused by the further pyroclastic and debris flow, unmanned constructions, that is, tele-operation of construction machines and off-highway dump trucks, have been and are being done under the threat of avalanche of earth and rocks, land slide, or rock falls in the Unzen restoration project.

The unmanned construction is introduced to a disaster recovery or reconstruction under the following conditions:

- Workers should be safe from any danger while they are working;
- The structure of the check dam being constructed should stand up to debris flow;
- The construction period should be short; and
- Enormous volcanic deposits existing around the construction site should be utilized effectively.

The unmanned construction has two folds shown in figure 1. The one such like venous work is applied to remove unstable rocks and sediment from sand pockets, for example, a collection of sediment by a bulldozer, digging and loading by a backhoe, and haulage by dump trucks. The other such like arterial work is applied to build multilayer sediment control dam against debris flow as shown in picture 1.

As shown in picture 2, in the unmanned construction, tele-operators would ensure concurrent and subsequent reliable operation of their construction machines and off-highway dump trucks as watching monitors that display the visual work scenes in the time and space domain. The visual

work scenes are fed back by cameras mounted on the construction equipment and the construction machine.

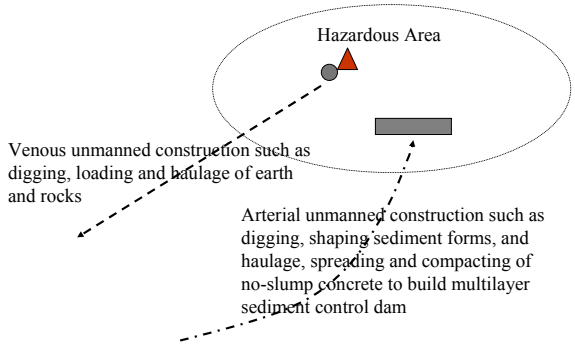

Fig. 1 Unmanned construction in the hazardous area under the threat of avalanche of earth and rocks, land slide, or rock falls

Picture 1 Multilayer sediment control dam

Picture 2 Tele-operation

Picture 3 Unmanned construction of multilayer sediment control dam

2. COLLABORATION, COMMUNICATION, CONSTRUCTION AND INTELLIGENT MANAGEMENT

The collaboration, communication, construction and intelligent management (C3IM) is a comprehensive, web-enabled system to enhance collaborative works and interactive communication, and to grasp significant information in order to support the unmanned construction, which aims to manage a fleet to ensure reliable construction operations at points on construction in such a hard environment. The fleet means the complement of construction machines, dump trucks, and workers that are working together. The C3IM has a site process database in which are preserved as-planned data and as-built data, and also has select and display menu, that is, levels of security right down to the individual field level to ensure that only properly authorized individuals have access to certain confidential data or the ability to delete important information.

The C3IM comprises construction target management system, ICT-based work management system and construction profile management system, and could make process control loops with electronic data exchange among them as shown in Figure 2.

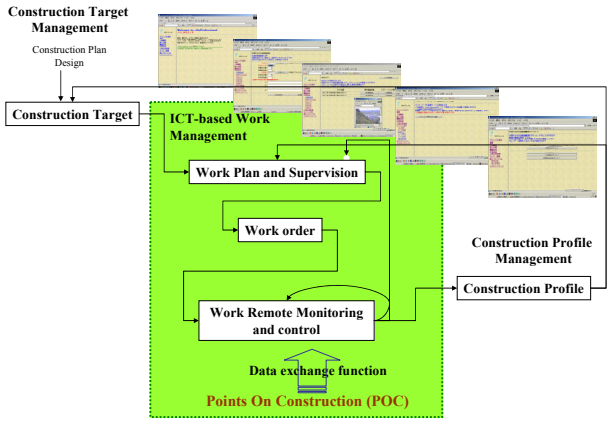

Fig.2 Framework of the C3IM

The construction target management system helps resident engineers and supervisors to choose the best construction resources for the task routing and scheduling. The ICT-

based work management system are described in the chapter 3. The construction profile management system could automatically edit gathered field data to produce daily and monthly reports. The construction profile here is defined as a set of data to vision characteristics of phenomena being generated along with construction in progress and as indices to show their patterns [2].

3. ICT-BASED WORK MANAGEMENT

The ICT-based work management system helps resident engineers, supervisors and others to manage basic data and day-to-day construction tasks. The basic data means fleet description that represents properties of construction machines, dump trucks, workers, and communication tools that are formed as construction resources. The ICT-based work management is composed of many functions. Staple functions of those are zoning, work plan and supervision, points on construction (POC), data exchange, work remote monitoring and control, communication all at once to take shelter, drive bearing evaluation.

3.1 Work plan and supervision

Operation area of mobile entities is zoned into task routes such as loading spot, haulage route, transferring or dumping spot, and compartments of concrete placement as shown in figure 3.

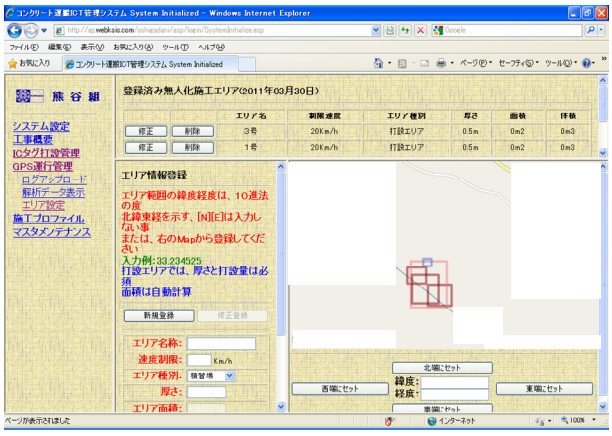

Fig.3 Example of compartments of concrete placement being zoned

Based on as-built data regarding work performed at the task route and the each work cell, such as the each pitch time[3], it would give supervisor and resident engineers relevant information on allocation of construction resources for the task routing and scheduling. Here, examined are the following matters:

- Sizing fleet of machines right,
- Minimizing transport movement,
- Optimizing material usage, and
- Planning allocation and performance of construction machinery, dump trucks and on-site personnel.

3.2 Work order

Based n the work plan, supervisor will issue work order daily as shown in figure 4.

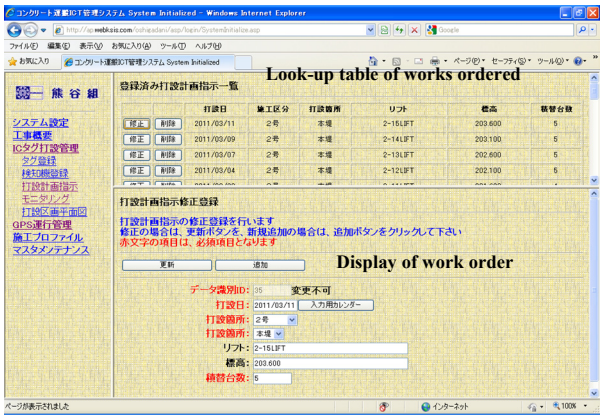

Fig. 4 Example of display of work plan order

The supervisor informs gang leaders and others of work orders and safety instructions.

3.3 POC

The POC means a site network tracking system for mobile entities, and could play a large role in construction field. In the POC, are used a number of transmitting and receiving base station and nodes, web camera, GPS receivers, cellular phone, PDA, satellite antenna, which connect through mediums of wireless communication, wired link communication, or satellite communication with the function of work remote monitoring and control. Here, the data-exchange function works to send work information to, and conversely capture field data from a ground station computer, which is one of components of the POC.

3.4 Work remote monitoring and control

The work remote monitoring and control function supports thinking and decision-making support to:

- Provide workers with opportunities to recognize potential hazards, develop proactive countermeasures and start monitoring; and
- Pick a set of building block of information at the right level of abstraction and stimulate or guide worker's creative thinking, i.e., indication or hint.

The display of the remote monitoring and control on the PC gives information on the work in progress at one-minute intervals, and shows early colored warnings based on the imminent left time allowable to work. Also, the information can be confirmed by a cellular phone. It enables us to supervise the work in progress continuously on a real time basis.

3.5 Communication all at once to take shelter

Any workers carry their own active tags and cellular phone with GPS receivers. Specific spots such as dugout and shelter on the way where workers should run are designated in advance. Transmitting and receiving base station is put in position on the side of the entrance to the each spot. The base station successively receives signals from an active tag with workers who come into the effective cover range, and then send the work remote monitoring and control function with the active tag ID received and the time stamps of the ingress to and egress from the spot, in other words, its effective radio range.

Corresponding to hazard levels, supervisor could transmit notice, caution, or warning to them all at once through their cellular phone. Menu of the communication all at once to take shelter is shown in figure 5. Figure 6 shows an example of alert mail. Title and content of mail is categorized in advance into several fixed forms corresponding to the hazard levels.

In addition, they could be confirmed where they were and which way they took by watching the display of the work remote monitoring and control.

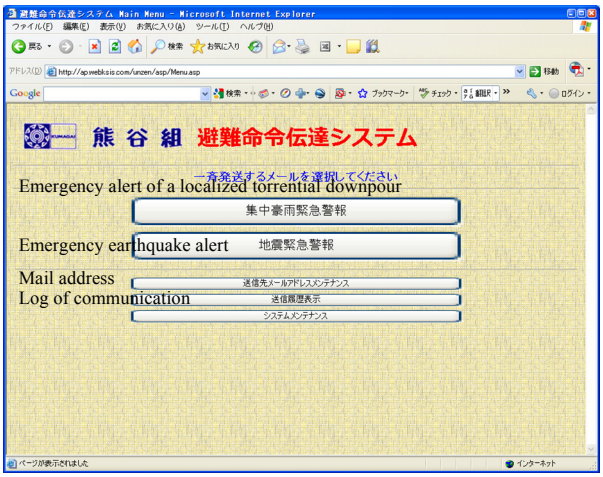

Fig. 5 Menu of the communication all at once to the shelter

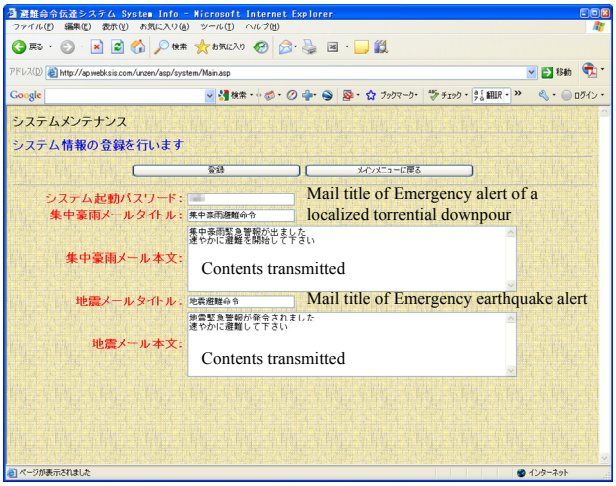

Fig. 6 Example of alert mail.

3.6 Drive bearing evaluation

The drive bearing represents driver's behavior, which might impact construction efficiency and energy-saving regarding haul work [3]. The drive bearing is explained and found by explanatory variables, which include departure and arrival times, time elapsed for work performed at each work cell, distance travelled, number of round trips, average payload of a dump truck, velocity (travel speed), accelerations, number of changes in acceleration and deceleration, jerks, trip time (loaded, empty), round trip time, cycle time per day or hour, and driving footprint. Drivers carry GPS receivers with their

dump trucks. These numeric values are calculated from the GPS data regarding the foot prints of their drives.

4. APPLICATION OF ICT-BASED WORK MANAGEMENT

The ICT-based work management has been applied to unmanned construction of multilayer sediment control dam using sediment forms in the Unzen restoration project. Figure 7 gives an overview of no-slump concrete haulage and placement.

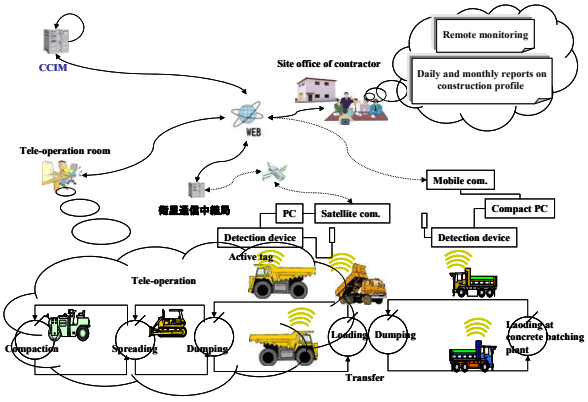

Fig. 7 Overview of no-slump concrete haulage and placement

No-slump concrete here is hauled by 10 ton dump trucks from ready-mixed concrete batching plant to the spot where it is transferred to off-highway dump trucks as shown in picture 4. Subsequently, the off-highway dump trucks haul the no-slump concrete to the designated dumping spot as shown in picture 5. In addition, a bulldozer spreads the no-slump concrete, and subsequently a vibration roller compacts it in picture 6. Here, two off-highway dump trucks, a bulldozer and a vibration roller are tele-operated.

The base station at the ready-mixed concrete batching plant and the transfer spot is connected via mobile communication with the Internet. The beginning and end of loading and dumping to transfer no-slump concrete are captured by the sensor-based event detection system. On the other hand, in this tele-operation, the operator intervention approach is introduced to recognize occurrences related to dumping by the off-highway dump truck, spreading by the bulldozer, or compacting by the vibration roller [1].

Picture 4 Transfer spot of no-slump concrete

Picture 5 Dumping spot of no-slump concrete

Picture 6 Spreading and compacting of no-slump concrete

The event detection system here is capable of identifying events within a mount of short time through a process of the no-slump concrete transportation and placement. The event detection system automatically sends the work

remote monitoring and control the data related to the events identified.

The work remote monitoring and control would display two types of information. The one is to display haulage of no-slump concrete in progress by 10 ton dump trucks and off-highway dump trucks as shown in figure 7.

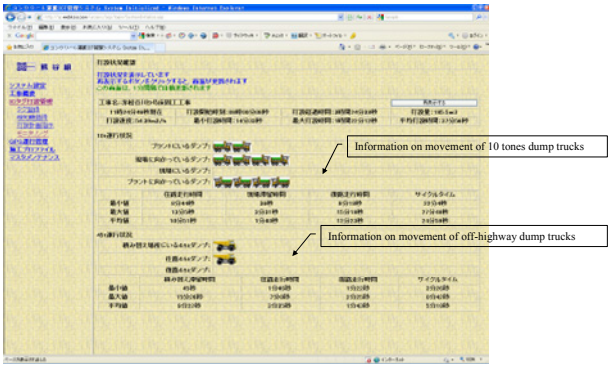

Fig.7 Information on haulage of no-slump concrete in progress

The other is to display information on time control over concrete placement as shown in figure 8.

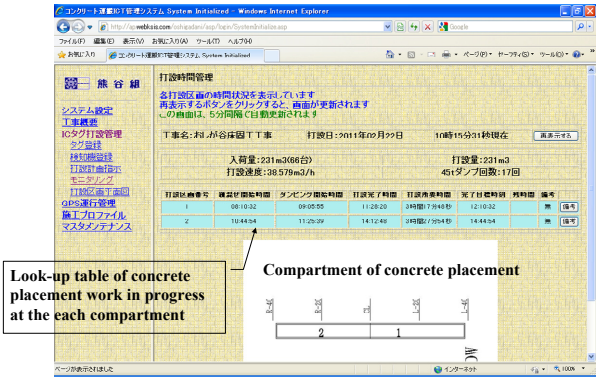

Fig. 8 Information on time control over concrete placement

The information on the display gives the current construction profile in progress at one-minute intervals. Also, the information on the display can be confirmed by a cellular phone. As watching the display, tele-operators, supervisors and resident engineers are able to recognize early colored warnings based on the imminent left time allowable to place the no-slump concrete. The early colored warnings consist of the colored classes such as “Blue” means the completion, “No-colored” the left time equal to or more than one hour, “Yellow” the left time less than one hour, and “Red” the left time less than thirty minutes.

5. REMARKS

The ICT-based work management remote monitoring and management system gives a detailed visibility into appearances and motions in the unmanned construction, and enables the decision-makers to take quick actions with the objective of increasing construction safety and efficiency on daily duty-cycle.

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